California Environmental Protection Agency
Environmental Technology Certification Program

Evaluation of the

BP Solar

Photovoltaic Apollo Thin Film Solar Module

August 1998

I. INTRODUCTION

This report discusses the technology used by BP Solar Incorporated (BP Solar) in the design of its Apollo® Photovoltaic Module, the performance claims to be verified by the Air Resources Board (ARB), the design review, the emissions estimation techniques and results, and the findings and recommendations of the ARB staff concerning the photovoltaic module.

A. Products of Combustion

In an effort to make progress towards attaining healthy air quality in California, regulations restrict emissions of sulfur oxides (SO_X), nitrogen oxides (NO_X), carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOC) from a broad spectrum of activities. Sulfur oxides, NO_X, CO, PM, VOCs, and carbon dioxide (CO_2) are formed as products of combustion. The reduction of these combustion emissions from fossil fuel-fired (oil, natural gas, and coal) electrical generation facilities is one part of California's clean air strategy to achieve and maintain healthy air quality in California.

1. Sulfur oxides (SO_X)

SO_X are by-products of the combustion of fossil fuels. SO_X can cause adverse effects on the human respiratory system. They can also contribute to the formation of secondary particulate matter and acid rain.

2. Nitrogen oxides (NO_X)

NO_X are by-products of the combustion of fossil fuels. NO_X can cause adverse effects on the human respiratory system. Through a complex series of atmospheric reactions, NO_X can contribute to the formation of ground-level ozone, secondary particulate matter, and acid rain.

3. Carbon monoxide (CO)

CO is a by-product of incomplete combustion. CO can adversely affect the ability of blood to deliver adequate amounts of oxygen to the human body.

4. Particulate matter (PM)

PM is emitted directly as a by-product of incomplete combustion or as windblown dust from agricultural operations, construction activities, or dry lake beds. PM can adversely affect the respiratory system and can cause decreased visibility. Fine particulate matter (less than 2.5 microns in size) is particularly hazardous to health.

5. Volatile organic compounds (VOC)

VOCs are emitted directly as by-products of incomplete combustion or as fugitive emissions from sources such as petro-chemical operations and solvent-containing products. Through a series of complex atmospheric reactions, VOCs contribute to the formation of ground-level ozone.

6. Carbon dioxide (CO_2)

CO_2 is a by-product of complete combustion. CO_2 is a "greenhouse gas" that can contribute to global warming.

B. Organization of this Report

This report is organized into several sections. The first section, General Information, provides background information on the ARB's precertification program, as well as the BP Solar Apollo® Photovoltaic Module (Apollo® PV

Module) being evaluated. The next four sections: Summary of Scope; Statement of Claims; Materials Available for Evaluation; and Description of Technology discuss the breadth of our evaluation, the performance claims for the Apollo® PV Module, the information that we relied on to conduct our evaluation, and a detailed description of the Apollo® PV Module (Model BP 925L).

The following three sections: Technical Evaluation; Evaluation of Claims; and Test Results present detailed information on our technical review and assessment of the performance of the Apollo® PV Module (Model BP 925L). The sections entitled: Quality Management and Environmental and Economic Benefits provide supporting information on BP Solar's procedures to produce modules which meet the company's claims. These sections also provide a brief assessment of the potential environmental and economic impacts of the technology.

Finally, the remaining sections: Recommendations and Precertification Conditions discuss the ARB staff's determination of the performance of the Apollo® PV Module (Model BP 925L) relative to the company's claims. These sections also provide some guidance with respect to the specific conditions that must be met for the certificate to remain valid for three years. The Appendices contain additional information supporting the evaluation in this report.

II. GENERAL INFORMATION

Under the regulations established for the program, equipment or processes eligible for Precertification must: 1) have an air quality benefit; 2) be commonly-used or have the potential to be commonly-used in the near future (market ready); and 3) not pose a significant potential hazard to public health and safety and the environment. Furthermore, to be eligible, applicants for the program must demonstrate that they have sufficient control over the manufacture of the equipment or process to ensure that they can consistently and reliably produce equipment which performs at least as well as that considered in this evaluation.

A. Equipment Precertification Program Background

The Equipment and Process Precertification Program (Equipment Precertification Program) is a voluntary statewide program for manufacturers of commonly-used equipment or processes. A precondition for entry into the program is that the equipment has an air quality benefit. On June 14, 1996, the ARB adopted section 91400 of the California Code of Regulations which incorporates the Criteria for Equipment and Process Precertification (Criteria). The regulation and Criteria were approved by the California Office of Administrative Law on October 31, 1996 and became effective on November 30, 1996.

Under the Equipment Precertification Program, manufacturers request that the ARB conduct an independent third-party verification of performance claims which focus on the air quality benefits of its equipment or process. If the claim is verified, the manufacturer is free to refer to the results of the ARB staff's evaluation in its marketing literature. Upon successful completion of the verification process, the applicant may also request that the ARB staff notify specific air pollution control and air quality management districts (districts) in California of the ARB's determination. As a result of the ARB's notification, the district has an advanced opportunity to become familiar with the performance of the equipment or process.

On March 26, 1998, the ARB received an eligibility request from BP Solar that the ARB staff determine if the Apollo® PV Module (Model BP 925L) was eligible for the Equipment Precertification program. After receiving confirmation from ARB staff that the Apollo® PV Module (Model BP 925L) was eligible for the program, BP Solar submitted a precertification application package. As part of our review of the application package, we evaluated design information, emissions estimation techniques and results, along with other information concerning the performance of the Apollo® PV Module (Model BP 925L) to determine whether the claims were verifiable.

B. Relationship to Air Quality

In an effort to make progress towards attaining healthy air quality in California, regulations restrict emissions of SO_X, NO_X, CO, PM, VOCs, and CO_2 from a broad spectrum of activities. The reduction of these emissions from electrical generation facilities is one part of California's clean air strategy. In California, electricity is typically generated from fossil fuel-fired power plants, which employ a variety of air pollution control devices and practices to reduce emissions. Because the use of the Apollo® PV Module (Model BP 925L) eliminates or reduces emissions from electricity generation, the ARB evaluated Apollo® PV Module (Model BP 925L) as air pollution control equipment.

C. Health and Environmental Impacts

As part of our evaluation, staff conducted a cursory review of the potential environmental impacts associated with the Apollo® PV Module (Model BP 925L). Based on this review, we concluded that the Apollo® PV Module (Model BP 925L) would not likely present health or environmental impacts significantly different from those associated with other air pollution control equipment for electrical generation systems, which are currently in wide use throughout California. Please note that BP Solar and/or purchasers of the Apollo® PV Module (Model BP 925L) are required to meet all applicable health and safety standards with respect to the manufacture, installation, use, and maintenance of the Apollo® PV Module (Model BP 925L).

D. Manufacture / Ownership Rights

The recommendations in this report are contingent upon BP Solar having the legal rights to produce and/or market the Apollo® PV Module (Model BP 925L). BP Solar documented its ownership of these rights in their Eligibility Request Form, dated March 26, 1998, which stated "The applicant is the manufacturer of the technology for which eligibility is requested."

III. SUMMARY OF SCOPE

BP Solar claims that because the Apollo® PV Module (Model BP 925L) is not a combustion device, its use as an electrical generation device will not result in any products of combustion, specifically emissions of SO_X, NO_X, CO, PM, or CO_2. In addition, BP Solar claims that emissions of VOCs from an adhesive contained in the Apollo® PV Module (Model BP 925L) are calculated to be no greater than 0.012 grams per year. Generally, the control of SO_X, NO_X, CO, PM, VOCs, and CO_2 from fossil fuel-fired electricity generation facilities involves using efficient air pollution control equipment, combustion control modifications, increased monitoring and inspection frequency, and improved maintenance practices.

IV. STATEMENT OF CLAIMS

The following are the claims verified by ARB staff concerning the BP Solar Apollo® PV Module (Model BP 925L). The verification of these claims is predicated on the presumption that the Apollo® PV Module (Model BP 925L) is installed, operated, and maintained in accordance with manufacturer's instructions.

1. **The Apollo® Photovoltaic Module (Model BP 925L) is a non-combustion device without the potential for emissions of SO_X, NO_X, CO, PM, and CO_2.**

2. **The Apollo® Photovoltaic Module (Model BP 925L) has a calculated emission rate of VOCs that is no greater than 0.012 grams per year.**

V. MATERIALS AVAILABLE FOR EVALUATION

The following materials were used by the ARB, as part of its evaluation of BP Solar's Apollo® PV Module (Model BP 925L).

1. Request to Determine Eligibility for the ARB Equipment Precertification Program from Mr. James Emming of BP Solar to Ms. Kitty Martin of the ARB, transmitting the Eligibility Request Form and the BP Solar brochure entitled Putting the Sun to Work, March 26, 1998.

2. Letter from Mr. Richard Corey of the ARB to Mr. James Emming of BP Solar notifying BP Solar that the Apollo® Photovoltaic Module (Model BP 925L) was eligible for the ARB Precertification of Equipment or Process Program and transmitting an estimate of fees required for precertification, March 30, 1998.

3. Application for the ARB Equipment Precertification Program from Mr. James Emming of BP Solar to Ms. Kitty Martin of the ARB, transmitting an application fee and the application (with attached Product Development Record, copy of California State Board of Equalization Seller Permit, Underwriters Laboratories Certification Information, Green Seal Certification Information, User Manual, Confidential Quality Management Information, Product Warranty, and a List of Customer References), April 2, 1998.
4. Letter from Mr. Richard Corey of the ARB to Mr. James Emming of BP Solar notifying BP Solar that ARB had received its application and application fee, that its application was sufficiently complete, and that some minor

informational items were still required of BP Solar, April 9, 1998.

5. Memorandum from Mr. Raymond E. Menebroker of the ARB's Stationary Source Division to Mr. George Lew of the ARB's Monitoring and Laboratory Division requesting assistance in methods and test protocol review for verification testing for BP Solar, April 9, 1998.

6. Memorandum from Mr. James Loop and Ms. Cindy Castronovo of the ARB's Monitoring and Laboratory Division to Mr. Richard Corey of the ARB indicating that no measurable emissions would be expected to be detected from the Apollo® Photovoltaic Module using current methods for evaluating stationary sources, April 16, 1998.

7. Letter from Mr. Richard Corey of the ARB to Mr. James Emming of BP Solar thanking Mr. Emming for the tour of the BP Solar manufacturing facility in Fairfield, California and documenting the discussion items, April 29, 1998.

8. Letter from Mr. James Emming of BP Solar to Ms. Kitty Martin of the ARB providing an outline of a VOC emissions estimation study and a timeline for providing the revised claim language and figures, May 8, 1998.

9. Memorandum from Mr. Raymond E. Menebroker of the ARB's Stationary Source Division to Mr. George Lew of the ARB's Monitoring and Laboratory Division requesting assistance in reviewing the VOC emissions estimation study outline submitted by BP Solar, May 14, 1998.

10. Memorandum from Mr. James Loop and Ms. Cindy Castronovo of the ARB's Monitoring and Laboratory Division to Mr. Richard Corey of the ARB's Stationary Source Division approving the VOC emissions estimation study outline as submitted by BP Solar, June 4, 1998.

11. Letter from Mr. Richard Corey of the ARB to Mr. Danny Cunningham of BP Solar informing BP Solar that the VOC emissions estimation study outline had been approved and confirming the timeline for submittal of revised claim language, drawings, and a sample module, June 17, 1998.

12. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing electronic files that contained revised drawings of the Apollo® Photovoltaic Module, June 23, 1998.

13. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing language that described "off-grid" and "grid-tied" application of the Apollo® Photovoltaic Module, June 30, 1998.

14. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing a first draft of the VOC emissions estimate study, June 30, 1998.

15. Memorandum from Mr. Raymond E. Menebroker of the ARB's Stationary Source Division to Mr. George Lew of the ARB's Monitoring and

Laboratory Division requesting assistance in reviewing the draft VOC emissions estimation study submitted by BP Solar, July 2, 1998.

16. Facsimile transmission from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing the Materials Safety Data Sheet for the adhesive contained in the Apollo® Photovoltaic Module, July 2, 1998.

17. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing revised claim language, July 2, 1998.

18. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing revised language regarding the operation of the Apollo® Photovoltaic Module, July 2, 1998.

19. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing a revised drawing of the Apollo® Photovoltaic Module, July 2, 1998.

20. Memorandum from Mr. James Loop and Ms. Cindy Castronovo of the ARB's Monitoring and Laboratory Division to Mr. Richard Corey of the ARB's Stationary Source Division providing comments on the VOC emissions estimation study submitted by BP Solar, July 7, 1998.

21. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing a revised draft of the VOC emissions estimate study for the Apollo® Photovoltaic Module, July 15, 1998.

22. Personal delivery by Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB of two sample Apollo® Photovoltaic Modules, June 20, 1998.

23. Electronic mail transmittal from Mr. Danny Cunningham of BP Solar to Ms. Kitty Martin of the ARB providing a final draft of the VOC emissions estimate study for the Apollo® Photovoltaic Module, July 21, 1998.

24. Memorandum from Mr. Raymond E. Menebroker of the ARB's Stationary Source Division to Mr. George Lew of the ARB's Monitoring and Laboratory Division requesting assistance in reviewing the final draft of the VOC emissions estimation study submitted by BP Solar, July 28, 1998.

25. Memorandum from Mr. James Loop and Ms. Cindy Castronovo of the ARB's Monitoring and Laboratory Division to Mr. Richard Corey of the ARB's Stationary Source Division approving the final draft of the VOC emissions estimation study submitted by BP Solar, July 30, 1998.

26. BP Solar's Quality Management Practices and Standards, Reviewed by Ms. Kitty Martin of the ARB at BP Solar's Manufacturing Facility in Fairfield, California, July 30, 1998.

27. Log of telephone conversations between the staff of the ARB and the staff of BP Solar.

For information on how to obtain these materials, please call the ARB staff contact at the phone number provided on the inside cover of this document.

VI. TECHNOLOGY DESCRIPTION

BP Solar's Apollo® PV Module (Model BP 925L) is a self-contained power producer. The 14-inch by 48-inch modules, rated at 25 watts, use a thin film semi-conductor to capture and convert sunlight into electricity. The thin film technology can be manufactured much cheaper than traditional thick, silicon solar cells. The film is thin enough to allow the modules to be used as windows, skylights, or other similar architectural features.

As shown in figure 1, the photovoltaic device consists of two layers of semiconductor material encapsulated between two sheets of glass, which absorb light (photons) and convert it to electrical energy (volts). The semi-conductor layer closest to the sunlight is called the window layer, because in addition to acting as the n-type (negative) semi-conductor, it also transmits light. The thicker p-type (positive) layer of the semi-conductor is located behind the window layer. The p-layer absorbs the majority of the light and, by natural phenomenon, converts this light to electricity.

The n/p configuration of the semiconductor layers generates an electrical field, which promotes migration of the electrons. The electrons generated in the p-layer migrate to the n-layer. This migration constitutes an internal electric current. The internal current needs to be collected and transferred to an external circuit or load for it to produce power. Thin films of metal, deposited on the semiconductor layers collect the internal current and direct it to external cables. Approximately six percent of the captured sunlight is converted to electricity; the remainder is dissipated from the module as heat energy.

BP Solar's Apollo® PV Module (Model BP 925L) is based on an n-cadmium sulfide (CdS)/p-cadmium telluride (CdTe) diode deposited on glass. The process to manufacture BP Solar's Apollo® PV modules starts with a chemical bath batch process that deposits CdS onto glass plates that have been previously coated with a conducting oxide. Each batch of glass is then uniformly electro-deposited with a very thin film of CdTe in another deposition bath. As shown in figure 2, this is followed by a series of three rapid laser scribings (approximately 0.1 centimeters apart) to produce a series of interconnecting cells to build up the appropriate voltage output. A metal (aluminum) is deposited on the glass after the second scribing. Using ethyl vinyl acetate (EVA), a back cover glass layer is adhered to the scribed front glass plate. The edges of the module are sandblasted to create a smooth surface and function as a moisture barrier. Finally, mounting brackets and copper electrical leads (14 American Wire Gauge) are attached to the rear plate of the module. Figure 2 displays the front, back, and end views of the completed Apollo® PV Module (Model BP 925L).

Once it is in the external cables, the direct current (DC) power can be used in many applications where stand-alone energy is required. The Apollo® PV Module (Model BP 925L) can be connected in two ways, one for off-grid applications and the other grid-tied applications.

The direct current power generated from the Apollo® PV Module (Model BP 925L) can be utilized for off-grid applications, such as remote lighting, remote water pumping, and powering of loads for remote homes and telecommunication sites. In direct current applications such as water pumping, the Apollo® PV Module (Model BP 925L) can be connected directly to the load, thus limiting water pumping to daylight hours. However, in most off-grid applications, the power generated from an Apollo® PV Module (Model BP 925L) goes through a charge controller and is stored in a battery for use as needed. The charge controller ensures that the battery is never over-charged. The controller typically disconnects the module at night to prevent reverse flow into the Apollo® PV Module (Model BP 925L) at night from the battery.

The direct current power generated from an Apollo® PV Module (Model BP 925L) can also be used for grid-tied applications, such as load sharing, peak power shaving, and "net billing." In these applications, the output of the Apollo® PV Module (Model BP 925L) is connected to a direct-current-to- alternating-current (DC to AC) converter (inverter) which allows the module to power standard AC loads.

The following is a listing of the technical specifications of the Apollo® PV Module (Model BP 925L).

Minimum Power	25 watts
Rated Voltage	16.6 Volts (V)
Rated Current	1.51 Amps (A)
Open Circuit Voltage	22.0 V
Short Circuit Current	2.0 A
Maximum System Operating Voltage	600 V
Maximum Series Fuse	3.0 A

Following is a description of the systems and components of two typical Apollo® PV Module (Model BP 925L) configurations.

Residential Application

In this scenario, a 2 kilowatt AC grid-connected system is installed to allow net metering. The system is not required to be roof-mounted and is connected to the grid via an inverter, which converts DC to AC power. The typical components would be as follows:

Modules:	(84) Apollo® PV Modules (Model BP 925L)
Connection:	(28) strings of 3 modules in series
Steel Structure:	Support for modules
Structure Area:	Approximately 350 square feet
Distribution Box:	Houses cable connections, fuses, by-pass diodes
Inverter:	Converts the DC power to grid-compatible AC power, typically single phase, 110-120 V, includes solid state control electronics
Connection to Grid:	System is connected to grid via output of inverter

Battery Charging Application

In this scenario, a 100 watt DC battery charging system is used for fluorescent tube lighting applications in a rural environment. The modules would be wired in a configuration that supplies 16.6 V (DC) at maximum power point. A charge regulator regulates the DC power to accommodate for battery "state of charge". Some charge regulators have special features that induce battery gassing to promote electrolyte mixing prior to charging. This helps overcome electrolyte stratification. Energy storage is achieved using 12 V lead acid batteries, because they are robust and can tolerate deep and partial discharge. The typical components would be as follows.

Modules:	(4) Apollo® PV Modules (Model BP 925L)
Connection:	(4) modules in parallel
Steel Structure:	Support for modules incorporating conduit
Structure Area:	Approximately 20 square feet
Distribution Box:	Houses cable connections, fuses, by-pass diodes
Charge Regulator:	A suitable regulator to maximizes battery “state of charge”
Battery Bank:	The number of 12 V, lead-acid batteries depends on the load and use requirements
Load:	Typically fluorescent tubes with a DC ballast

VII. TECHNICAL EVALUATION

A. <u>Design Review</u>

The staff of the ARB conducted a design review of the Apollo® PV Module (Model BP 925L) and confirmed that it is not a combustion device. As such, no measurable emissions of SO_X, NO_X, CO, PM, or CO_2 would be expected from its operation using current methods for evaluating stationary sources. Although no VOCs would be expected to be measured by currently-available stationary source methods, BP Solar proposed a paper study that included an upper-bound calculated emission rate of VOCs that could be emitted from the adhesive that is used in the Apollo® PV Module (Model BP 925L).

B. <u>VOC Emissions Estimate Study</u>

BP Solar prepared a paper study that included an upper bound estimate of the VOC emissions that would result from the EVA adhesive that is used to bind the two glass layers in the Apollo® PV Module (Model BP 925L). The upper-bound calculated emission rate of VOCs was estimated in the paper study to be no greater than 0.012 grams per year. Prior to conducting the paper study, we requested that an outline of the study be prepared and approved by the ARB staff. We received the outline on May 8, 1998, and notified BP Solar that we approved it on June 17, 1998. BP Solar submitted a final version of the paper study (contained in Appendix A) on July 21, 1998. On July 28, 1998, we notified BP Solar that we concurred with the findings, including the VOC emission estimates. In summary, the included an estimate of the VOC emissions that would be expected to result from the EVA adhesive that is used to adhere the two glass plates to each other in the Apollo® PV Module (Model BP 925L). Butanol and acetone are the residual VOCs that were identified in the paper study as potentially diffusing from the sandblasted glass perimeter edge of the Apollo® PV Module (Model BP 925L). It was assumed that these compounds diffuse from the perimeter edge uniformly over 20 years. The estimated emissions for acetone were 0.005 grams per year per module. The estimated emissions for butanol were 0.0065 grams per year per module. Therefore, the total calculated VOC emissions estimated from the Apollo® PV Module (Model BP 925L) were 0.012 grams per year.

At the request of the ARB staff, BP Solar also estimated the emissions from the two typical applications for the Apollo® PV Module (Model BP 925L). These applications, the residential and battery charging, are described in detail in Section VI. The total calculated VOC emissions estimated from the residential application is 0.97 grams per year. The total calculated VOC emissions estimated from the battery charging application is 0.046 grams per year.

VIII. EVALUATION OF CLAIMS

This section presents additional information relating to the claims verified by the ARB as part of this evaluation report. As stated earlier, the ARB's evaluation and recommendations presented in this report are predicated on the expectation that the Apollo® PV Module (Model BP 925L) is installed, operated, and maintained in accordance with the manufacturer's instructions. Below are supporting comments, which may be used to interpret the significance of the claims verified in this report. To assist the reader, each claim is displayed in bold text.

1. The Apollo® Photovoltaic Module (Model BP 925L) is a non-combustion device without the potential for emissions of SO_X, NO_X, CO, PM, and CO_2.

Our verification of this claim is based on our evaluation of the information discussed under Section V. The claim language is precise because it must directly correlate with the supporting documentation included with the application package. Based on our evaluation, the Apollo® PV Module (Model BP 925L) should be treated as a non-combustion device from the perspective of emissions of SO_X, NO_X, CO, PM, and CO_2. Given that no combustion occurs during the generation of electricity by the Apollo® PV Module (Model BP 925L), no emissions of SO_X, NO_X, CO, PM, and CO_2 would be expected. As such, the Apollo® PV Module (Model BP 925L) would not be expected to obtain an air quality permit from air pollution control or air quality management districts (districts) in California.

1. The Apollo® PV Module (Model BP 925L) has a calculated emission rate of VOCs that is no greater than 0.012 grams per year.

The emission rate presented in the claim is an upper bound estimate (i.e., actual emissions are expected to be lower) of the VOC emissions (butanol and acetone) that result from the EVA adhesive that is used to bind the two glass layers in the Apollo® PV Module (Model BP 925L). The upper-bound emission rate calculation for VOC emissions assumed that the VOC emission rate was linear over the 20 year lifetime of the Apollo® PV Module (Model BP 925L).

The expected VOC emission rate for two typical Apollo® PV Module (Model BP 925L) applications was estimated by BP Solar. The first application, a 2 kilowatt AC grid-connected system would require the use of 84 Apollo® PV Modules (Model BP 925L). The annual upper-bound VOC emissions from this application were calculated to be no greater than 0.97 grams per year. The second application, a 100 watt DC battery charging system would require the use of 4 Apollo® PV Modules (Model BP 925L). The annual upper-bound VOC emissions from this application were calculated to be no greater than 0.046 grams per year per system.

Because the VOC emissions are minimal from the Apollo® PV Module (Model BP 925L), it would not be expected to obtain an air quality permit from air pollution control or air quality management districts (district) in California.

IX. TEST RESULTS

The staff of the ARB conducted a design review of the Apollo® PV Module (Model BP 925L) and confirmed that it was not a combustion device. As such, no measurable emissions of SO_X, NO_X, CO, PM, or CO_2 would be expected from its operation using current methods for evaluating stationary sources. In addition, the ARB staff reviewed and found acceptable a paper study prepared by BP Solar that included an upper bound estimate of the VOC emissions that result from the adhesive that is used to bind the two glass layers in the Apollo® PV Module (Model BP 925L). The upper-bound calculated emission rate of VOCs was estimated in the paper study to be no greater than 0.012 grams per year.

X. QUALITY MANAGEMENT

A. <u>Practices and Standards</u>

BP Solar has developed extensive quality management practices and standards for its Apollo® PV Module (Model BP 925L). A number of quality management practices, including the use of an environmental chamber and a reference light standard, are conducted to ensure that the product meets safety requirements and performance guarantees. The practices and standards are described in detail in the Quality Management Manual, which was reviewed by the ARB staff at the BP Solar manufacturing facility in Fairfield, California.

BP Solar's Quality Management Program was reviewed by the ARB staff as part of our evaluation of the Apollo® PV Module (Model BP 925L). The ARB staff has determined that the quality management program is sufficiently comprehensive to support certifying the BP Solar Apollo® PV Module (Model BP 925L).

B. <u>Other Certifications</u>

BP Solar has submitted an application for Underwriters Laboratories (UL) 1703 "Safety Standards for Flat Plate Photovoltaic Modules" for the Apollo® PV Module (Model BP 925L). Currently, the Apollo® PV Module (Model BP 925L) is being tested by UL with certification pending. In addition, BP Solar has submitted an application for Green Seal certification of the Apollo® PV Module (Model BP 925L). Green Seal is an independent, non-profit organization that encourages the purchase of environmentally responsible products and services. It awards its Green Seal of Approval to products that cause significantly less harm to the environment than similar products. Green Seal is currently reviewing the Apollo® PV Module (Model BP 925L) application and certification is pending.

C. Warranties

BP Solar provides a 20-year warranty for solar modules. A copy of the warranty is provided in Appendix B.

XI. ENVIRONMENTAL AND ECONOMIC BENEFITS

As part of our review, we evaluated the potential air quality impacts of the Apollo® PV Module (Model BP 925L). The use of the Apollo® PV Module (Model BP 925L) will likely result in a significant reduction of SO_X, NO_X, CO, PM, VOC, and CO_2 emissions when compared to traditional fossil fuel-fired electrical generation facilities.

In addition to environmental benefits, there is also the potential for economic benefits. Photovoltaic devices such as the Apollo® PV Module (Model BP 925L) can be effectively applied in remote areas or areas for which electricity cannot be cost-effectively be provided. Photovoltaic devices provide an alternative in areas where the electric power infrastructure has not been developed. In addition, the recent de-regulation of the electricity industry in California has created increased interest on the part of consumers to attach to local electricity grids in anticipation of selling on-site sources of generation.

It should be also noted that under certain conditions, emission reductions resulting from the installation of the BP Solar Apollo® PV Module (Model BP 925L) to replace emitting sources (e.g., internal combustion engines) may be eligible for emission reduction credits. However, individual air districts in California should be consulted to determine the eligibility for any emission reduction credits.

As part of our evaluation, we also contacted current users of a prototype of the BP Solar Apollo® PV Module (Model BP 925L). The users of these devices indicated that they have been pleased with the performance of the modules. The ARB staff also visited the BP Solar manufacturing facility in Fairfield, California, which uses a series of interconnected Apollo® PV Modules (450 watts potential) as skylights for the building.

XII. RECOMMENDATIONS

After evaluating the information discussed in this report, the ARB staff recommends that the BP Solar Apollo® PV Module (Model BP 925L) be certified under its Equipment Precertification Program. Specifically, we have independently verified the claims of BP Solar concerning its Apollo® PV Module (Model BP 925L), as presented in the claims section of this report.

By accepting certification under the ARB's program, BP Solar assumes, for the duration of the three-year certification period, responsibility for maintaining the quality of the manufactured equipment and materials at a level equal or better than was provided to obtain this certification. Certification under the ARB's program is also contingent on the recipient agreeing to be subject to quality monitoring by the ARB, as provided by law.

The ARB makes no express or implied warranties as to the performance of the manufacturer's product or equipment. Nor, does the ARB warrant that the manufacturer's product or equipment is free from any defects in workmanship or material caused by negligence, misuse, accident, or other causes. The ARB staff believes, however, that BP Solar's Apollo® PV Module (Model BP 925L) will achieve the performance levels presented in the claims section of this report. Our determination is based on our evaluation of the data submitted by BP Solar, as well as, the other information identified in this report. Our recommendations are predicated on the expectation that installation and operation of the Apollo® PV Module (Model BP 925L) are performed in accordance with the manufacturer's specifications.

XIV. PRECERTIFICATION CONDITIONS

The recommendations in this report are conditional upon the Apollo® PV Module (Model BP 925L) being installed, inspected, and maintained, in accordance with BP Solar's recommendations. In order for the precertification to remain valid, BP Solar must retain the manufacturing rights for the Apollo® PV Module (Model BP 925L).